- Explain the general structure of RNA.
- Distinguish in terms of structures and roles, the three types of RNA.
- Define conjugated molecules and describe the roles of common conjugated molecules i.e. glycolipids, glycoproteins, lipoproteins and nucleoproteins.

Introduction

Biological molecules are present in living organisms such as proteins, carbohydrates, lipids, nucleic acids. The study of biological molecules, their processing and significance for living organisms is called to as **Biochemistry.** The knowledge of Biochemistry is important in many ways for example, to understand the working of biological systems, development in agriculture, pharmaceutical industries, food industries and more importantly for the expansion of field of genetics and biotechnology.

2.1 Biological Molecules in Protoplasm

All the matter of universe contains more than 100 elements although living organisms are composed of 25 elements, yet only 16 of these are essential for life. Six most common elements in all living organisms are hydrogen, carbon, oxygen, nitrogen, sulphur and phosphorous.

They account for about 99% of total mass of living organisms.

> **Do you know?**
>
> *Protoplasm is the living content of the cell that is surrounded by a plasma membrane. It is a general term for cytoplasm and nucleoplasm.*

Biological importance of hydrogen oxygen, nitrogen and carbon is largely due to their valencies having one, two, three and four respectively and their ability to form more stable covalent bond than any other element with same valencies.

Table 2.1 Approximate Chemical Composition of a Mammalian Cell

Water	70%
Protein	18%
Carbohydrate	4%
Lipids	3%
DNA	0.25%
RNA	1.1%
Other organic substances	
Enzymes, Hormones etc.	2%
Inorganic ions	1%

Table 2.2 Approximate Percentage of Bioelements in human body

Oxygen	65%
Carbon	18.5%
Hydrogen	9.5%
Nitrogen	3.3%
Calcium	1.5%
Phosphorus	1%
Potassium	0.4%
Sulphur	0.3%
Sodium	0.2%
Chlorine	0.2%
Magnesium	0.1%
Trace elements (14 types) less than	0.01%

Do you know?

The six most abundant elements in human body are oxygen, carbon, hydrogen, nitrogen, oxygen, calcium and phosphorus.

In biochemistry, **trace elements** are dietary elements that are needed in a very minute quantity for proper growth, development and functioning of the organism. Examples of trace elements are:

Copper, Boron, Chromium, Iodine, Zinc, Iron, Manganese, Cobalt, Fluorine, Silicon, Vanadium, Molybdenum, Tin and Selenium.

Macro-organic molecules:

There are four types of macro organic molecules in living things. These are proteins, carbohydrates, lipids and nucleic acids.

Do you know?

Macromolecules are made from many repeating units i.e., polymers and have higher molecular weight, while Micro molecules are individual units of polymers and have low molecular weight.

Protein are the most abundant organic compounds in protoplasm. Basic units of proteins are amino acids. Proteins are present in different forms like enzymes, hormones, antibodies etc. These are building materials of life.

Carbohydrates are composed of C, H, O and provide fuel for the metabolic activities of the cell, also store reserve food in cell.

Lipids are heterogenous groups of hydrophobic compounds, which act as reserved food stored and building material for cellular organelles.

Nucleic acids (DNA and RNA) are most essential organic compounds, for living organisms, their basic unit is nucleotide. DNA acts as hereditary material, while RNAs synthesize proteins under the instruction of DNA.

Main Metabolic Reactions in a Cell:

Condensation:

Specific small molecules when join together they form large molecule or

polymers. This process is called condensation, in which water is produced, while energy is used. During condensation, when two monomers join, an **OH^-** is removed from one monomer and **H^+** is removed from the other. The condensation is also called dehydration synthesis.

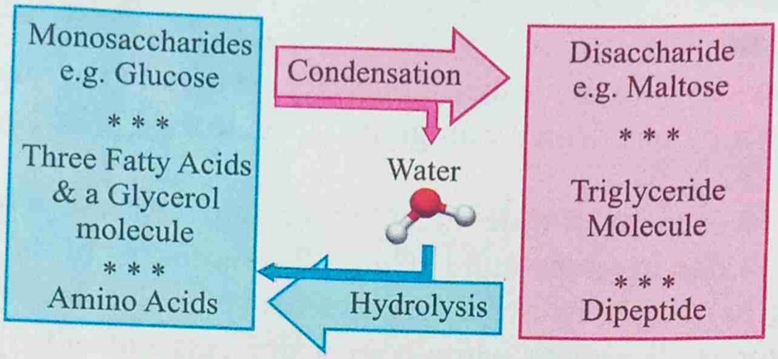


Fig. 2.1 Condensation and Hydrolysis

Hydrolysis:

Usually means the breakdown of polymer into monomers. In this process water is used, one monomer gets H^+ and other OH^- ion with the help of enzymes. When a bond is broken, energy is released. This process is also known as hydration.

2.2 Biological Importance of Water

Water is the most abundant component of protoplasm, with out it, life can not exist. It is important for different reasons; Such as vital chemical constituent of living cells and secondly it provides an environment for those organisms that live in water. The bodies of living organisms contain about 70-90% of water. Water has following important properties.

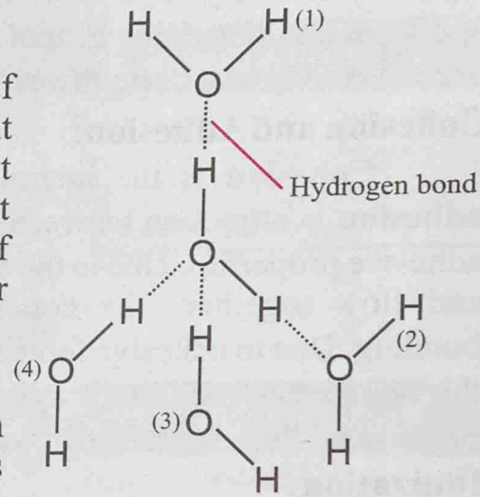


Fig. 2.2 Hydrogen bond

High Polarity:

Water is a polar molecule because its hydrogen contains slightly positive charge and oxygen contains slightly negative charge. A polar covalent bond is formed between hydrogen and oxygen atoms of water. Due to this polar covalent bond water is called polar molecule and thus it is universal solvent for polar substances, ionic compounds or electrolytes. The non-polar molecules having charged groups on their molecules can also be dissolved in water like sugar.

Do you know?

Bone contains only 20% water while brain 85% and blood 88%. The body of jellyfish contains 99% of water.

Hydrogen Bonding:

Hydrogen bond is electrostatic attraction between two polar groups that occurs when an hydrogen atom covalently bond to a highly electronegative atom such as oxygen, nitrogen and fluorine.

Due to hydrogen bonding water has a specific boiling and freezing point. (Boil at $100^{\circ}C$ and freezes at $0^{\circ}C$). The boiling and freezing point of water is important to sustain life on earth.

High Specific Heat:

The heat capacity of water is the amount of heat required to raise the temperature of one gram of water by one degree centigrade ($15^{\circ}C$ to $16^{\circ}C$), i.e., one calorie or 4.18 joules .

The high heat capacity of water means that a large increase in heat energy results in a relatively small rise in temperature. This is because most of the energy is used in breaking hydrogen bonds which restrict the movement of molecules. Due to this property of water, hot water cools slowly while cool water gets hot slowly. As a result the temperature of earth and living bodies does not change quickly and environment remains stable.

High Heat of Vapourization:

High heat of vapourization is a measure of the heat energy required to vapourize a liquid. A relatively large amount of energy is needed to vapourize water. This is due to hydrogen bonding. High heat of vapourization is useful for animals and plants to get rid of excess body heat during sweating, panting and transpiration etc.

Cohesion and Adhesion:

Cohesion is the intermolecular attraction between similar molecules while **adhesion** is attraction between dissimilar molecules. Water exhibit both cohesive and adhesive properties. Due to the cohesion water molecules stick together, remain in liquid and flow together. The cohesion is due to hydrogen bonding. Due to adhesive force water stick with the wall of the container (such as in xylem wall). This property is because of the polar nature of water.

Ionization:

It is the process by which an atom or a molecule acquires a negative or positive charge by gaining or losing electrons to form ions. On ionization water releases equal number of **H** and **OH** ions. The state of equilibrium is maintained at $25^{\circ}C$.

Hydrophobic Exclusion:

It is the reduction of the contact area between water and hydrophobic substances when placed in water. This property of water plays an important role in maintaining the integrity of lipid bilayer of all plasma membranes.

Tit bits

The heat of vapourization of water is 574 kcal/kg and evaporation of only 2ml out of one liter of water, lowers the temperature of remaining water by $1^{\circ}C$.

Tit bits

The part of compound that reacts with an other compound is called functional Group e.g., Hydroxyl Group, Keto Group, Aldehyde Group and Corboxyl Groups.

Density and Freezing Properties:

The density of water decreases below 4°C, therefore, ice is lighter than water, and tends to float. It is the only substance whose solid form is less denser than its liquid, because it has maximum hydrogen bonds. Ice insulate the water below it thus increases the chances of survival of organisms during winter.

2.3 Carbohydrates

These are organic compound, containing the elements of Carbon, Hydrogen and Oxygen in the ratio of 1:2:1. Their general formula is $C_x(H_2O)_y$, where **x** and **y** are variable numbers. Carbohydrates are also known as hydrated carbon because the number of hydrogen and oxygen atom is same as in water.

Chemically they are polyhydroxy aldehyde or ketone or complex substances.

Their chemistry is determined by aldehyde and ketone group e.g. aldehyde are very easily oxidized and hence are powerful reducing agents. Carbohydrates are commonly called sugars or saccharides.

Tit bits

Water is effective lubricant, prevent friction e.g. Tears protect the surface of eyes, from rubbing of eye lids, act as cushion around many organs (cerebro spinal fluid around central nervous system and amniotic fluid around foetus prevent from trauma).

Do you know?

The source of carbohydrates are green living things (e.g. Plants cyanobacteria, algae and many bacteria).

Classification:

There are three main classes of carbohydrates, that is monosaccharide, Oligosaccharide and polysaccharide.

Monosaccharide: (Gk. Mono: one, Saccharide: sweets or sugar)

They are simplest form of carbohydrates which cannot be hydrolyzed into simple units. The monosaccharides are small organic compounds made up of one sugar molecule, containing 3 to 7 carbon atoms.

They are very sweet in taste and easily soluble in water. All carbon atoms in a monosaccharide except one have a hydroxyl group while the remaining carbon either contain aldehyde or ketone. The sugar with aldehyde group is called aldo sugar and with ketone group is called keto sugar. Specific formula for monosaccharide is $C_n(H_2O)_n$ where, n is the number of carbon atoms in monosaccharides.

What are Vitamins?

Any of various organic substances that are essential for normal growth and nutrition. They are needed in minute quantities in the diet, act especially as coenzymes and precursors of coenzymes in the metabolic process but do not provide energy or serve as building unit. These are present in natural food stuffs or some times produced within body.

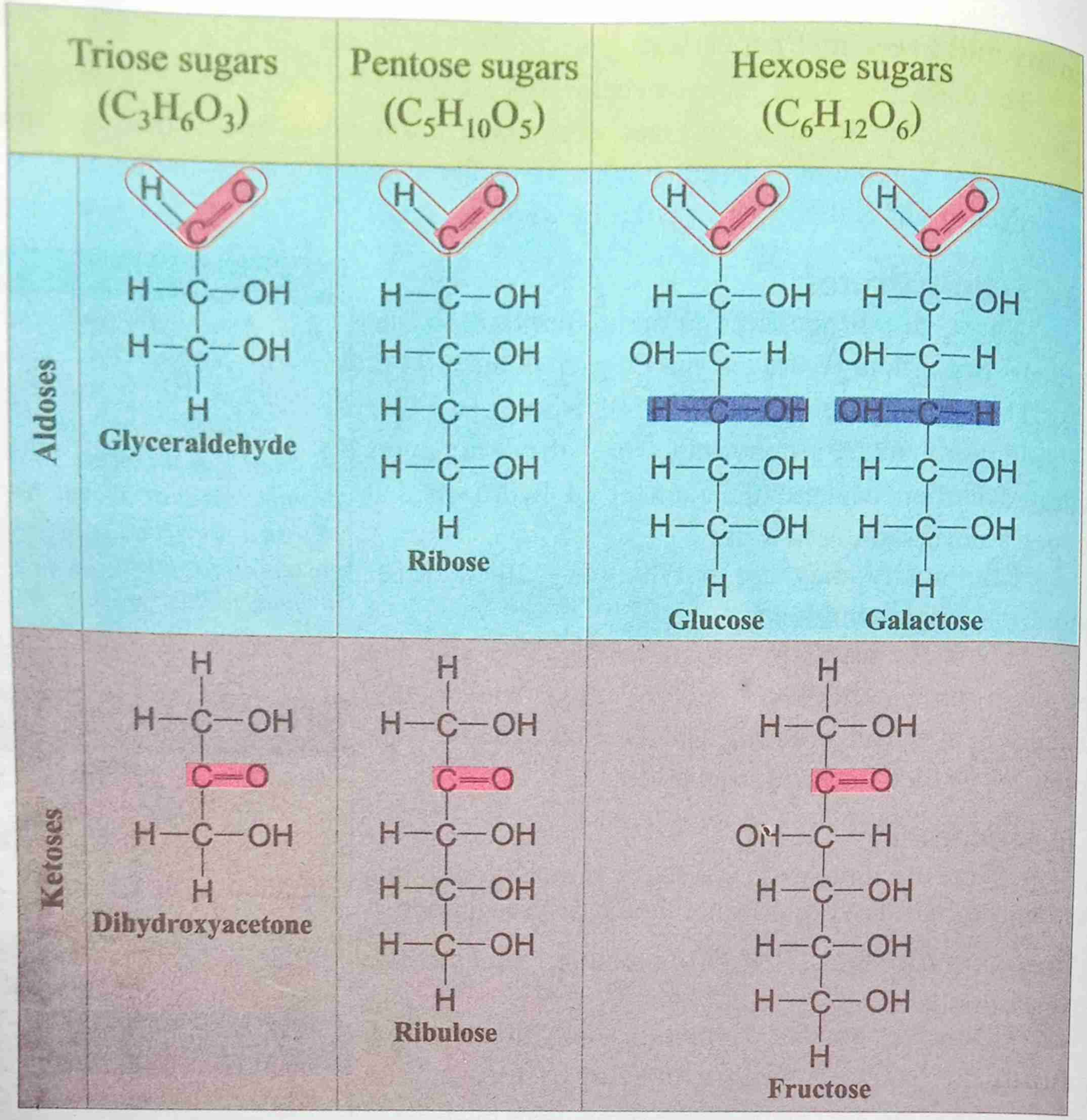


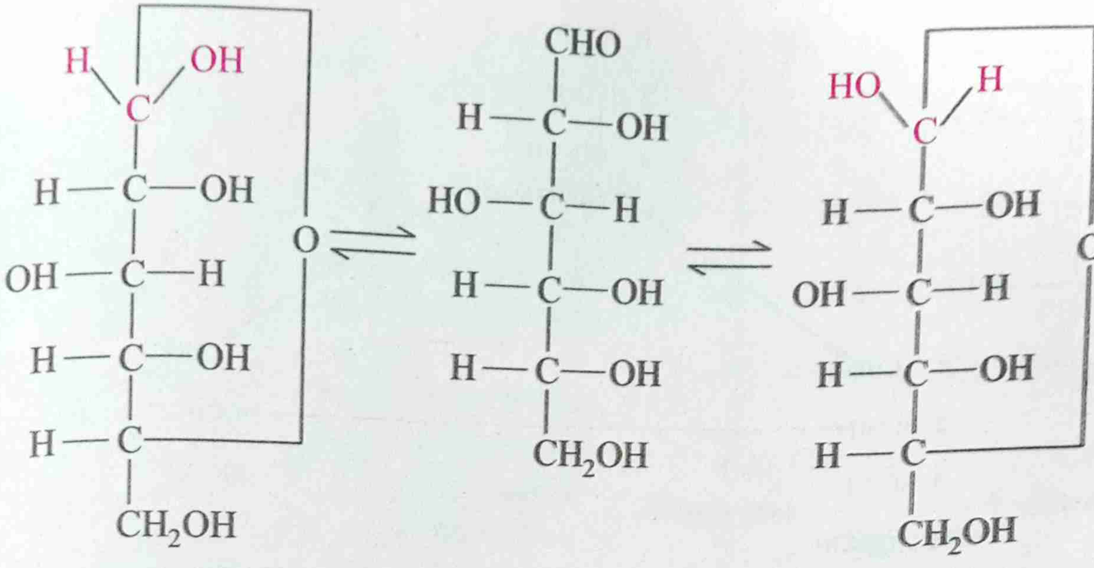
Fig. 2.3 Monosaccharides

Molecular and structural formula:

The molecular formula for a hexose is written as $C_6H_{12}O_6$. It is useful to show the arrangement of atoms in a molecule by a diagram which is known as structural formula.

Ring structure:

Pentoses and hexoses usually form rings in water. In pentoses and hexoses the chain of carbon atom is long enough to close up on itself and form a stable ring structure e.g. glucose. When glucose forms a ring, carbon atom No.1 joins to the oxygen on carbon atom No.5. The ring, therefore, contains oxygen and the last carbon of glucose is not part of ring.



Alpha D-glucose

Aldehyde form (free CHO)

Beta D-glucose

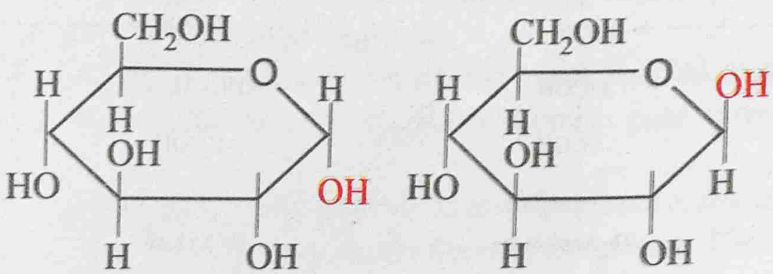


Fig. 2.4 Linear and ring forms

The hydroxyl group, (OH) on carbon atom number one may be above or below the plane of ring. If it is below the ring is known as alpha glucose (α -glucose) and if it is above then known as β-glucose (Beta glucose). The two different forms of same chemical is known as isomer.

Trioses:

Their formula is $C_3H_6O_3$ for example glyceraldehyde, dihydroxy acetone. These are intermediate substances in cellular respiration and photosynthesis.

Pentoses:

Their formula is $C_5H_{10}O_5$ e.g. ribose, deoxyribose and ribulose. Ribose is the component of RNA, ATP, NAD, FAD, NADP etc. Deoxyribose is the component of DNA while ribulose is the component of RUBP which is the CO_2 acceptor in photosynthesis.

Hexoses:

Their formula is $C_6H_{12}O_6$ e.g., glucose, fructose, galactose. Glucose is the most common respiratory substrate and also most common monosaccharide.

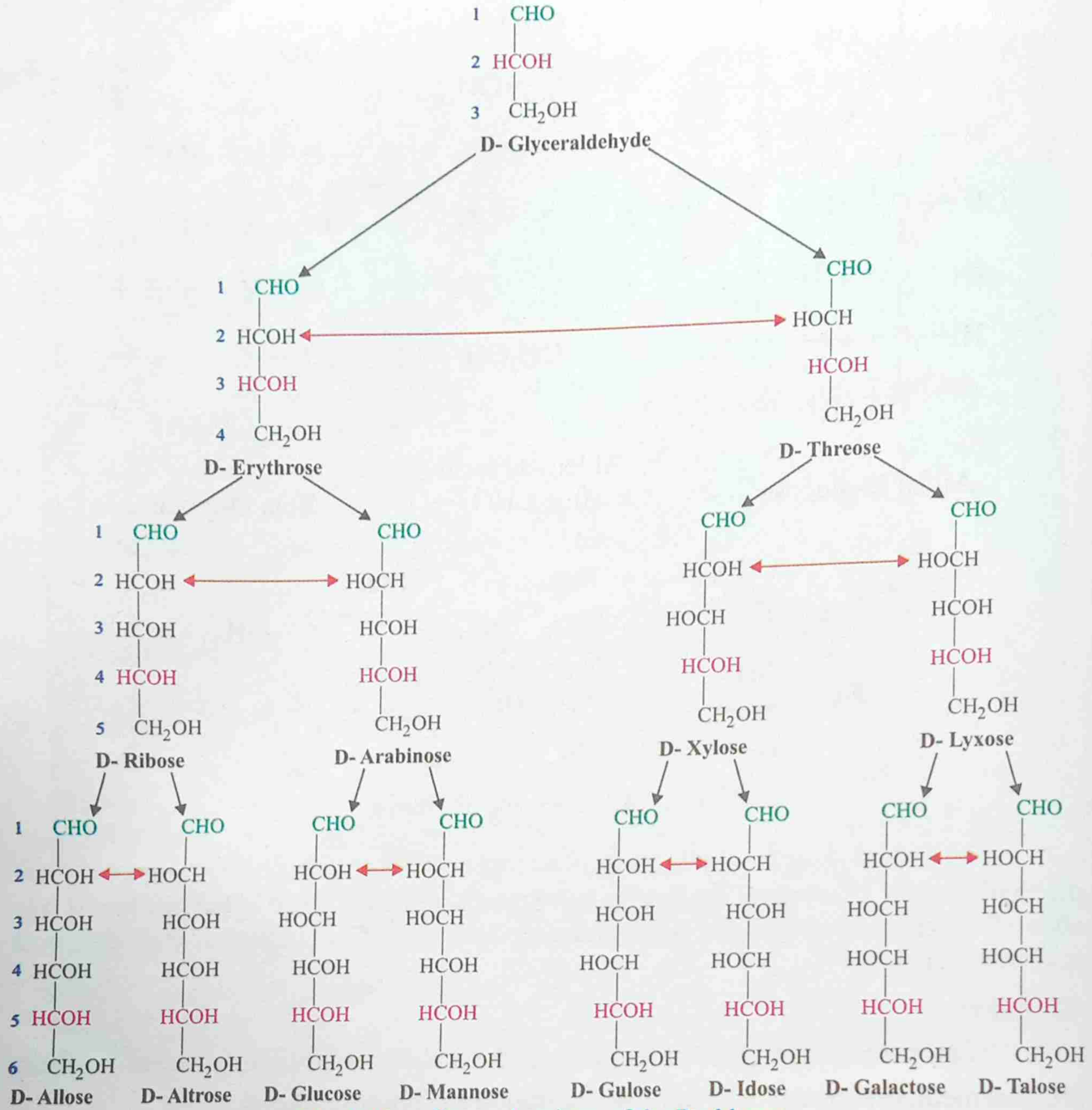


Fig. 2.5(a) Stereochemistry of the D-aldoses

Comparison between Structural Isomers and Stereoisomers:

Isomers (Gk. Iso: equal, meros: part) are molecules with the same molecular formula but different chemical structure. It means that isomers contain same number of atoms of each element but have different arrangements.

Isomers do not generally share similar properties,

> **Activity**
>
> *Can you justify that laboratory manufacturing sweetners are the left handed sugar and cannot be metabolized by the right handed enzyme.*

unless they also have same functional group. There are two main forms of isomerism, the structural isomerism and stereoisomerism.

In **structural isomers** (also called constitutional isomers) the atoms and functional groups are joined together in different ways, glucose and fructose are structural isomers.

In **stereo-isomerism** the bond structure is the same but the geometrical positioning of atom and functional groups in space differs e.g., **D-glucose** and **L-glucose.**

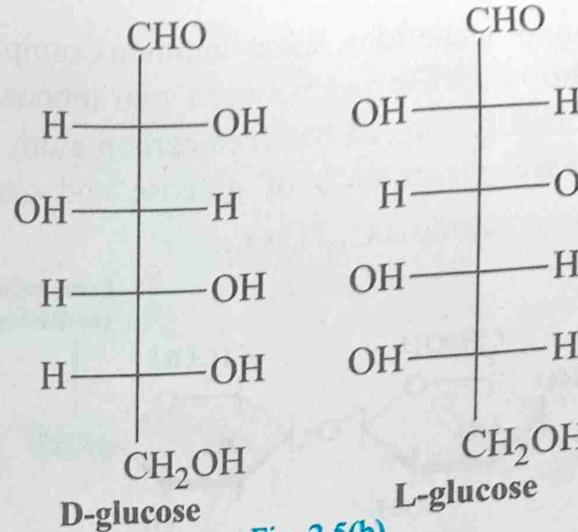


Fig. 2.5(b)

The Laboratory Manufactured Sweeteners are "Left - handed" Sugars:

Two forms of chemical compounds may exist, that are mirror image of each other. A suitable analogy is pair of gloves, they can be either left handed or right handed. Sugar are also left handed and right handed molecules.

Our digestive enzymes can only digest the right handed sugar molecules but generally do not digest the left handed and allow them to pass through body without digestion.

The LH sugar have same physical properties as D-glucose, therefore, may be used instead of D-glucose e.g., for baking and also making ice cream. The left-handed sugar are not commonly used because they are expensive, not commonly available and their over use cause serious disturbance for diarrhea patients. The laboratory manufactured sugar such as tagatose, sucralose etc. are examples of LH sugar. These sugar molecules can not be digested because mostly the enzymes for their digestion are not synthesized in the body and our cells do not have receptors for them. LH sugar are not converted into fats.

Oligosaccharides:

They are made up of 2 to 10 monosaccharides. Some examples of oligosaccharides are Disaccharides, Trisaccharides, Tetrasaccharides. The most common oligosaccharides are disaccharides.

Disaccharide:

It is made up of two monosaccharide (usually hexoses) combine by means of chemical reaction known as condensation.

Disaccharides are less sweet in taste and less soluble in water as compared to monosaccharides.

Disaccharides on hydrolysis give two

Tit bits

Malting is the process of converting of barley or other cereal grains into malt for use in brewing, distilling. This process takes place in malt house or malting floor.

monosaccharides, some common examples are maltose, lactose, sucrose and cellobiose. The bond formed between two monosaccharide is called glycosidic bond and it is normally formed between carbon atom 1 and 4 of neighbouring unit while in sucrose between carbon 1 of glucose and carbon 2 of fructose. The general formula of disaccharide is $C_{12}H_{22}O_{11}$.

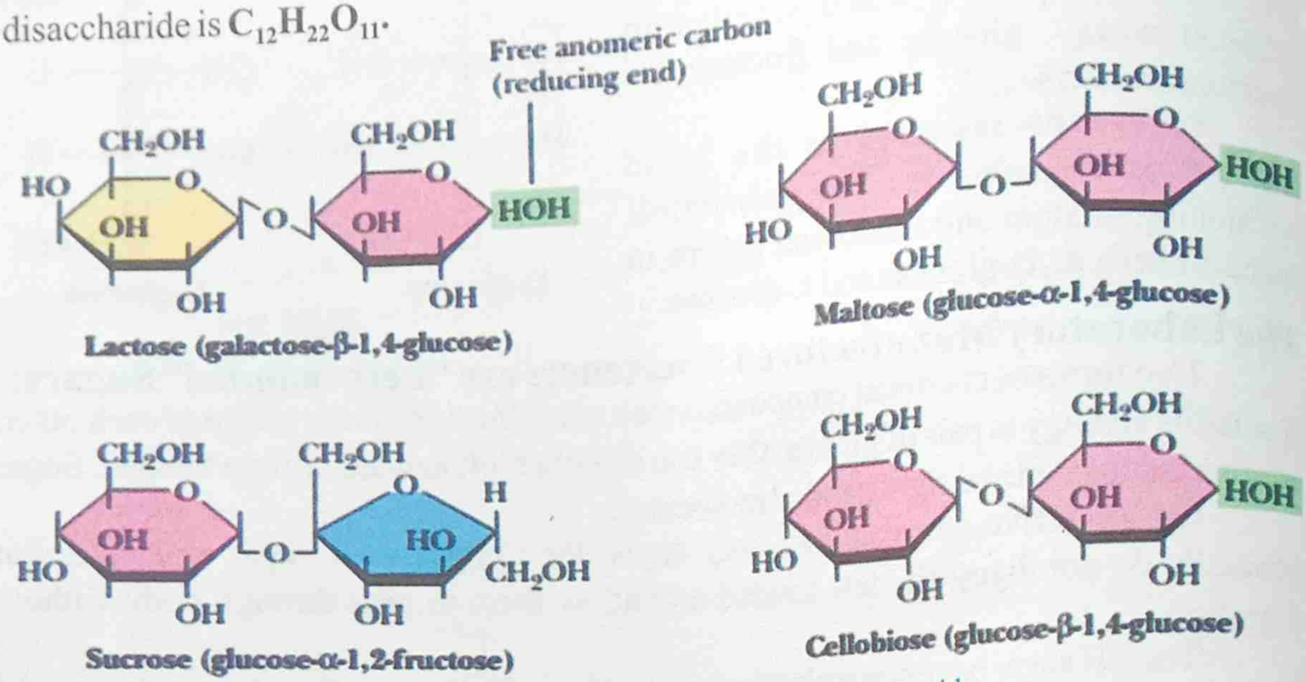


Fig 2.6 Structures of several common disaccharides.

The Role of Disaccharides:

Maltose is a disaccharide found in fruits and also found in our digestive tract as a result of breakdown product during digestion of starch by enzyme called amylase. It is also used in brewing industries to synthesize alcohol.

Lactose is milk sugar and it is an important energy source for young mammals. The **sucrose** or cane sugar is the most abundant disaccharide in nature and is hydrolyzed into glucose and fructose. It is obtained commercially from sugar cane or sugar beet, the sugar we normally buy in shops. All monosaccharides and some disaccharides including maltose and lactose are reducing sugars because these sugars can carry out a type of chemical reaction known as reduction. Sucrose is the most common non reducing sugar.

> **Tit bits**
>
> *Starch gives blue color when treated with iodine and gives many molecules of glucose on hydrolysis.*

> **Tit bits**
>
> *Glycogen gives a red color when treated with iodine while cellulose does not show any reaction with iodine thus does not give color.*

Polysaccharides:

Polysaccharides exhibit following properties. They are made up of several

monosaccharide, linked by glycosidic linkage may be branched or unbranched. They are tasteless and insoluble or some time sparingly soluble in water. They are most abundant in nature. Their general formula is $C_x(H_2O)_y$.

Types of polysaccharide:

Important polysaccharides are starch, glycogen, cellulose, dextrin, agar, chitin, pectin. All the above polysaccharides function chiefly as food, energy storage and structural material.

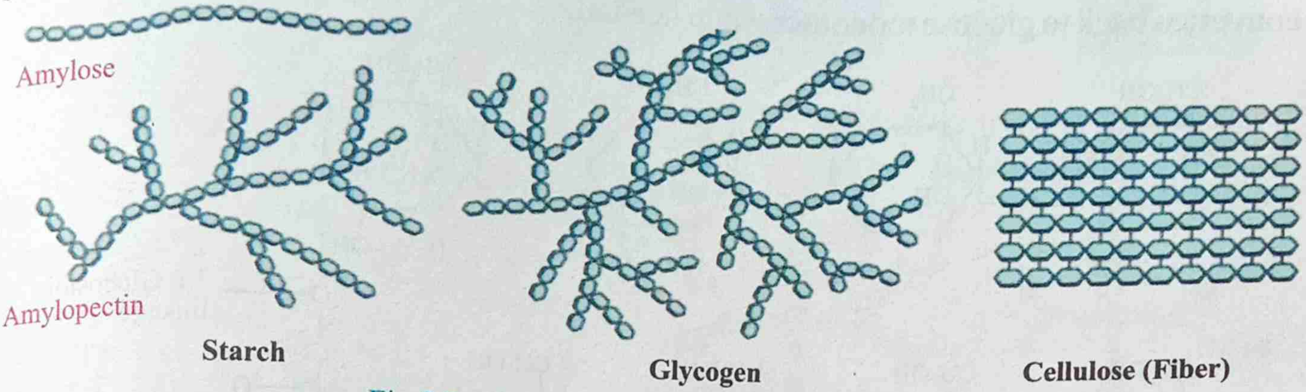


Fig.2.7 Different types of polysaccharides

Starch:

Starch is the polymer of glucose. It is major fuel store in plant and main source of food for animals. There are two types of starches, the simplest form is **amylose,** which has straight chain structure and joined by 1-4 **glycosidic** linkage. The other form is **amylopectin** which is more complexed and branched polymer with 1-6 linkage at branched point. Amylose is soluble in warm water but insoluble in cold water due to its simple structure while amylopectin is neither soluble in warm nor in cold water.

Cellulose:

It is a polymer of glucose and the most abundant carbohydrate in nature, unlike starch and glycogen it has structural role and main constituent of cell wall of plants and

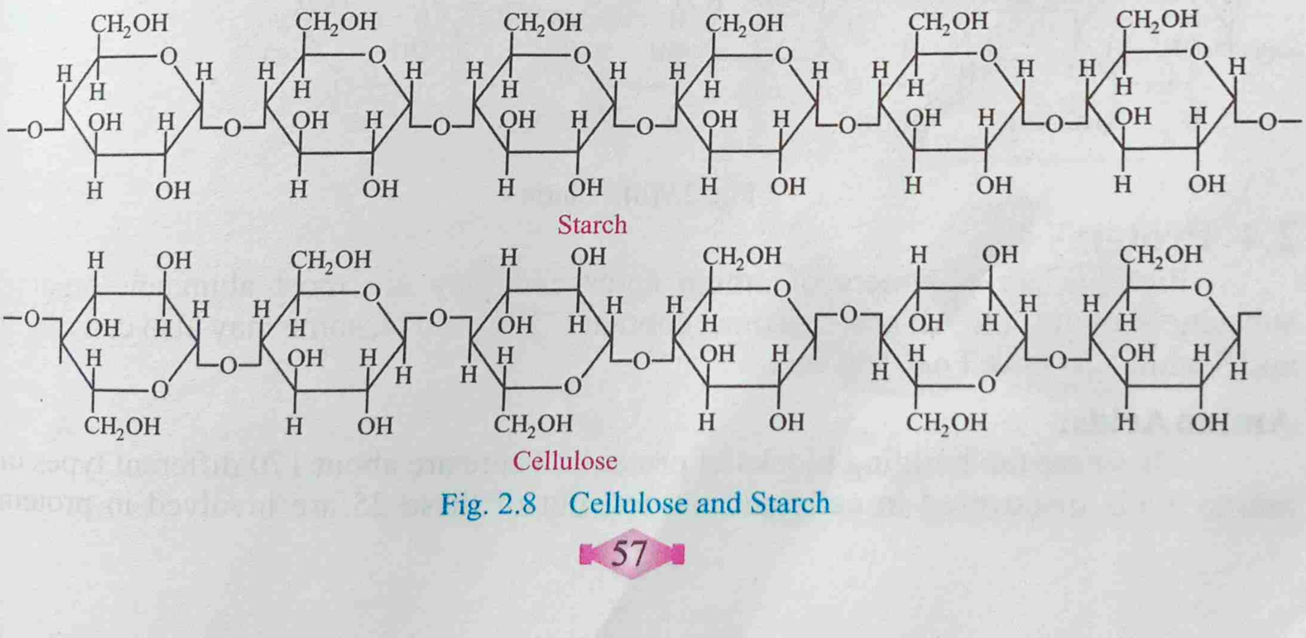


Fig. 2.8 Cellulose and Starch

algae. Cellulose is highly insoluble in water and we can not digest it because we do not have cellulase enzyme. However, herbivores can digest it because their digestive tract contain micro-organisms like bacteria, yeast, protozoans which secrete cellulase enzyme.

Glycogen:

It is a polymer of glucose and also called as animal starch. It is stored in liver and muscles. It is also found in fungi. It is insoluble in water due to complex structure and converted back to glucose monomer when needed.

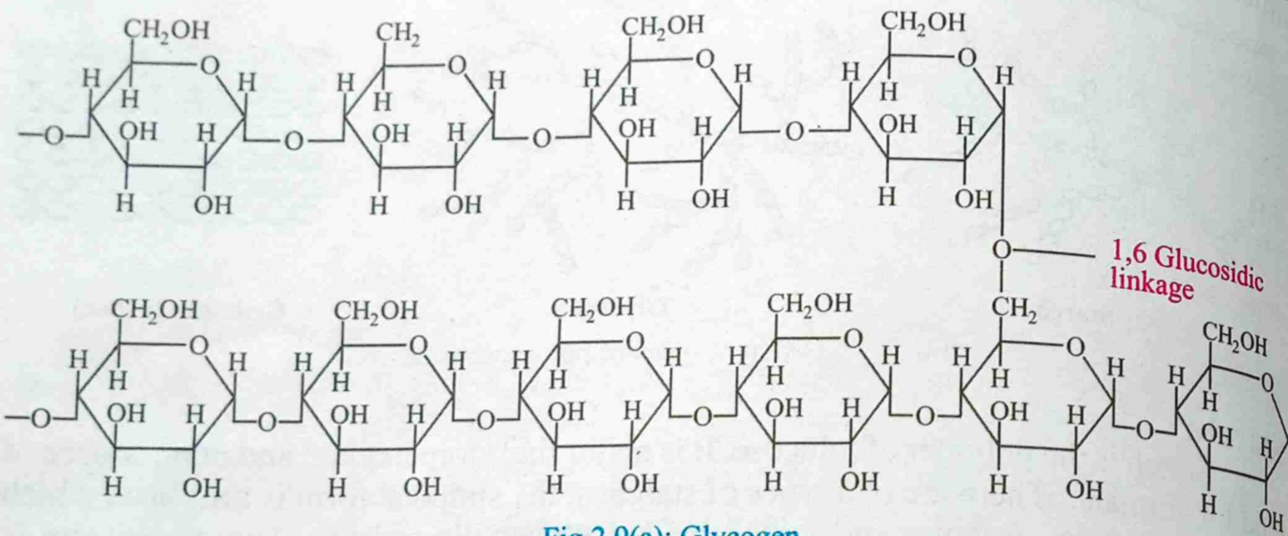


Fig.2.9(a): Glycogen

Chitin:

It is the structural nitrogenous polysaccharide and closely related to cellulose, found in cell wall of fungi and exoskeleton of arthropods.

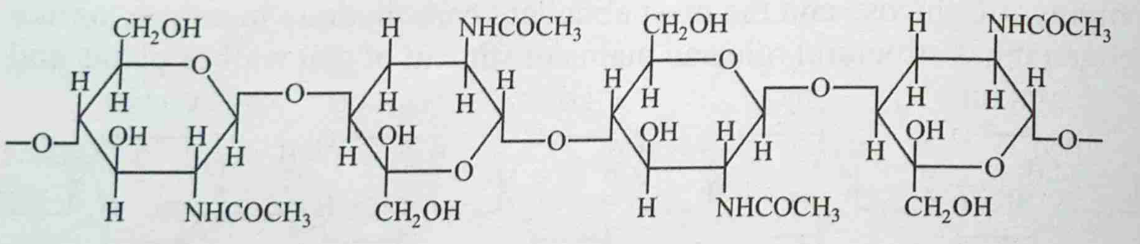


Fig. 2.9(b): Chitin

2.4 Proteins

Proteins are polymers of amino acids and they are most abundant organic substances in the cell. All proteins must contain C,H,O and N, some may also contain, P and S while few have Fe, I, Mg^+ etc.

Amino Acids:

These are the building blocks of proteins. There are about 170 different types of amino acids discovered in cells and tissues, out of these 25 are involved in protein

synthesis. Most proteins, however, are made up of 20 types of amino acids. Each amino acid consists of an alpha carbon. On one side of this alpha carbon NH_2 (amino group) is present while on other side COOH (Carboxylic acid group) is present.

On the third side Hydrogen is present while fourth side radical group is attached which is different in all amino acids.

Many amino acids are non essential because body of the organisms can synthesize them, thus are mostly not required as dietary food. Few amino acids are essential because they are required in diet.

2.4.1 Peptide linkage

Amino acids are linked together to from polypeptide chain. The linkage between amino acids are called peptide or amide linkage. One or more polypeptide chains unite to form a protein molecule. The peptide linkage is formed by the condensation reaction between the amino group of one amino acid and the carboxyl group of another amino acid. Water is released during this reaction.

2.4.2 Significance of sequence of Amino acids

Each protein molecule is composed of unique and specific arrangement of 20 different types of amino acids. The sequence is determined by the order of nucleotides in the DNA. The arrangement of amino acids in a protein molecule is highly specific for its proper functioning. If any amino acid is not in its normal place, the protein fails to carry on its normal function. Best example is the sickle cell anemia disease of human beings. The

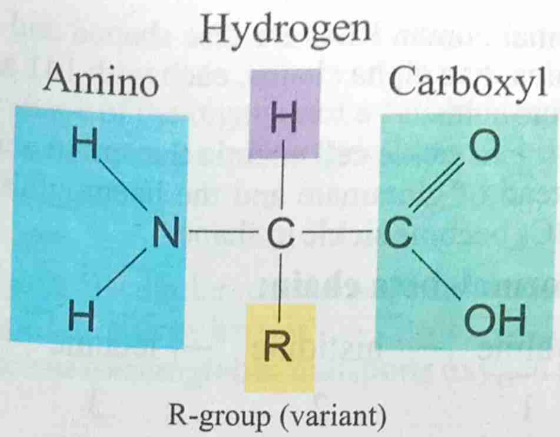


Fig. 2.10 An Amino Acid

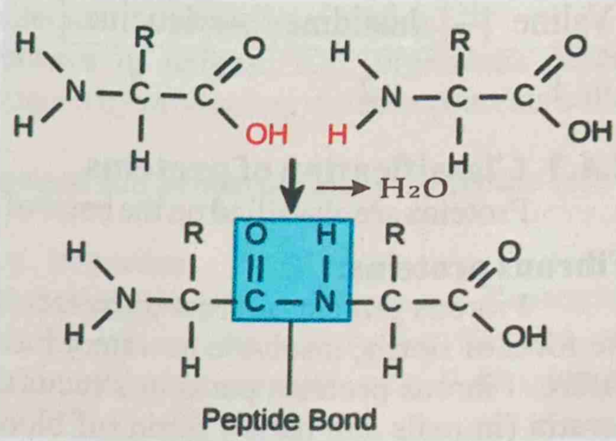


Fig. 2.11 A Dipeptide

Do you know?

Word protein has been derived from Greek word "proteios" which means prime or first.

Fig. 2.12 Sickle cell anemia

normal human RBC are disc shaped and the haemoglobin consists of four polypeptide chains, two alpha chains, each with 141 amino acids and two beta chains each with 146 amino acids.

In sickle cell anemia the amino acid no. 6 of beta chain of haemoglobin is valine instead of glutamate and the haemoglobin fails to carry any or sufficient oxygen and RBCs become sickle in shape.

Normal beta chain:

Valine (1) – histidine (2) – leucine (3) – threonine (4) – proline (5) – glutamate (6)

G Replaced by V ↓

Sickle cell anemia:

Valine (1) – histidine (2) – leucine (3) – threonine (4) – proline (5) – valine (6)

2.4.3 Classification of proteins

Proteins are classified on the basis of their shape into two types.

Fibrous proteins:

Fibrous proteins consist of molecules having one or more polypeptide chains in the form of fibrils, insoluble in watery medium. They are non-crystalline and elastic in nature. Fibrous proteins perform structural role in cells and organisms. Examples are keratin (in nails and hairs) fibrin (of blood clot), myosin (in muscle cells), silk fibers (from silkworm and spider webs) and collagen (connective tissues of skin, bones, ligament, tendon etc).

Globular proteins:

Globular proteins are spherical or ellipsoid in shape. This shape is due to multiple folding of polypeptide chains. They are soluble in watery medium, such as salt solution, solution of acids or bases or alcohol and can be crystallized. They can be disorganized with changes in the physical and physiological environment. Examples are enzymes, antibodies, many hormones, haemoglobin and myoglobin etc.

2.4.5 Role of Proteins

The proteins are very important organic molecules of living organisms. They are involved in all types of function of body. Each protein has a specific function.

Structural Role:

Proteins as structural components:

They build many structures of the cell. All known structures, exclusively or predominantly composed of proteins. Bones, nails, hair, flesh and even blood of higher animals also contain huge quantity of proteins.

Proteins provide mechanical support:

Many structural proteins determine the shape of the organ or of a cell and provide mechanical strength that protect soft and delicate organs or cell organelles e.g., bones, collagen fibers and cytoskeletons.

Functional role:

Enzymes are proteins, work as biocatalysts, all cellular reactions are catalyzed by enzymes which decrease the energy of activation i.e., energy barrier.

Many proteins help in transportation, such as **haemoglobin** transports oxygen and CO_2 gases.

Myoglobin is another protein complex that stores oxygen in the red muscles. Protein molecules also store energy in muscles of the body which supply energy to the body when outside source of food is inadequate such as **phosphocreatine.**

Proteins also provide immune responses or defense e.g., organisms defend themselves from the harmful effects of pathogens by producing, defense proteins called **antibodies** with in their body.

Blood clotting proteins such as **fibrinogen** and **prothrombin**, prevent the loss of blood from the body after an injury.

Proteins also regulate metabolic processes e.g., **hormones.**

Contractility is one of the most outstanding property of proteins. Contractile muscle proteins **(actin and myosin)**. Tubulin of microtubule **(cilia, flagella** and centrioles) help in the movement of chromosomes during anaphase of cell division are caused by proteins **(spindle fibers).**

2.5 Lipids

The lipids are a heterogeneous group of organic compounds which are insoluble in water but soluble in organic solvents like alcohol, ether, chloroform, acetone, and benzene etc. Lipids have greasy or oily consistency and include the compounds like fats, oils, waxes, cholesterol and related compounds.

Like carbohydrates, lipids are also composed of C, H and O. However, the percentage of oxygen in lipids is less than the carbohydrates which makes lipids lighter and make it much less soluble in water than most carbohydrates.

Due to hydrophobic property lipids form the structures like membranes, act as storage compounds and possess double energy as compared to carbohydrates due to high proportion of C-H bonds.

2.5.1 Classification and role of lipids

As lipids are heterogeneous substances and made up of different building blocks. So lipids are classified on the basis of solubility and the products obtained upon hydrolysis. There are following main groups of lipids.

- Acylglycerol
- Phospholipids

- Terpenes
- Waxes

Acylglycerol: (Neutral fats):

They are esters of fatty acids and glycerol. They are most abundant form of lipids in living things. An **ester** is a compound produced as a result of chemical reaction of any alcohol with any acid and release of a water molecule. In case of acylglycerol alcohol is glycerol. Glycerol is three carbon compound having OH group attached with each carbon atom.

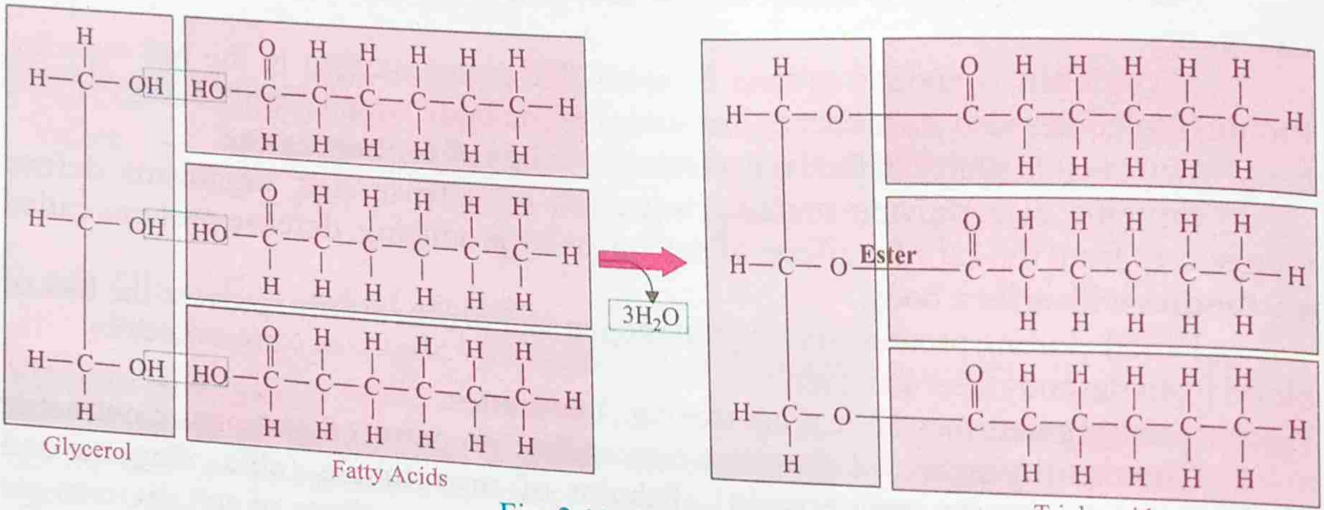


Fig. 2.13 Triglyceride

A fatty acid is a long straight chain of carbon atoms in even number (2-30) to which a carboxyl group is attached at the end. The acylglycerol may be in the form of monoglycerol, diglycerol or triglycerol depending on the number of fatty acids attached with glycerol. Triglycerol is most common among them.

There are about 30 types of fatty acids. These types of fatty acids vary in number of carbon atoms and bonds between carbon atoms (e.g., acetic acid 2 Carbons, stearic acid 18 Carbons).

A fatty acid may be **saturated** if it contains no double bond between carbon atoms or **unsaturated** if it contains 1—6 double bonds e.g. oleic acid.

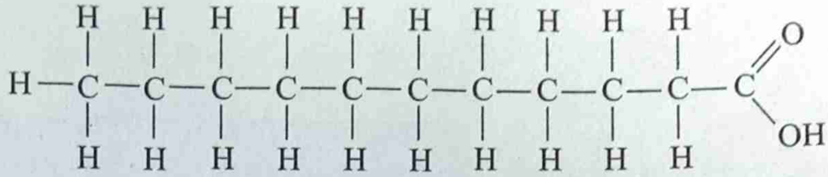
The saturated fatty acids are solid at room temperature, contain more energy due to high number of C—H bonds and mostly obtained from animals. On the other hand unsaturated fatty acids are liquid at room temperature, contain less energy due to less number of C—H bonds and usually obtained from plants.

Tit bits

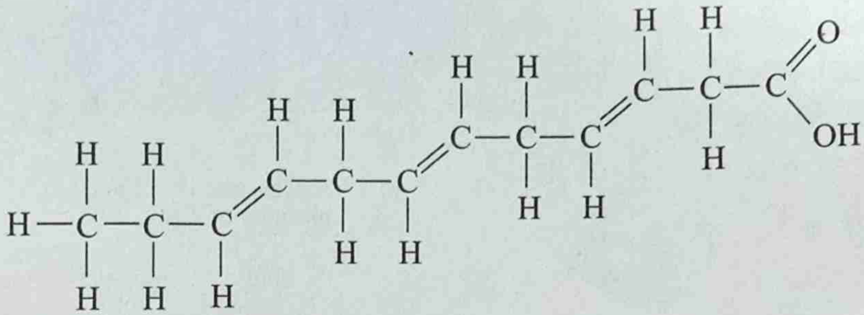
One gram of carbohydrate gives 4.1 Kcal, one gram of protein gives 4.6 Kcal while one gram of lipid gives 9 Kcal of energy.

Do you know?

Acylglycerol are called neutral fats because both acid and base are present in them.



Saturated Fatty Acid



Unsaturated Fatty Acid

Fig. 2.14 Saturated and Unsaturated Fatty Acids

Prostaglandins (PG):

The name prostaglandins is derived from prostate gland because it was first isolated from seminal fluid in 1935. It was believed to be part of prostatic secretions.

They are group of physiologically active lipid compounds having diverse hormone like effects in animals. Prostaglandins have been found in almost every tissue in human and other animals. They are derived enzymatically from fatty acids. Every prostaglandin contains 20 carbon atoms, including a 5 carbon ring.

In 1971 it was determined that aspirin like drugs could inhibit the synthesis of prostaglandin. The prostaglandins have a wide variety of effects such as cause dilation and contraction in smooth muscle cells, cause aggregation and disaggregation of platelets, regulate inflammation, regulate hormones, control cell growth, sensitize spinal neuron for pain, act on thermoregulatory center of hypothalamus to regulate fever etc.

Phospholipids:

Phospholipids are a class of lipids that are major components of all cell membranes. They can form lipid bilayers because of their **amphiphilic** characteristics. It`s molecule consists of 2 hydrophobic fatty acid tails and a hydrophilic head, consisting of phosphate group. The two components are joined together by a glycerol molecule. The phosphate group can be modified into nitrogenous organic compound such as choline, serine, ethanolamine etc.

> *Do you know?*
>
> ***Effects of too much fats in diet.***
>
> *Makes a person obese and also cause cardio vascular disorder like B.P, heart attack etc.*

In biological systems the phospholipids often occur with other molecules for example proteins, glycolipids, sterols and a bilayer such as "cell membrane". Lipid bilayers occur when hydrophobic tails line up against one another, forming a membrane of hydrophilic heads on both sides facing water.

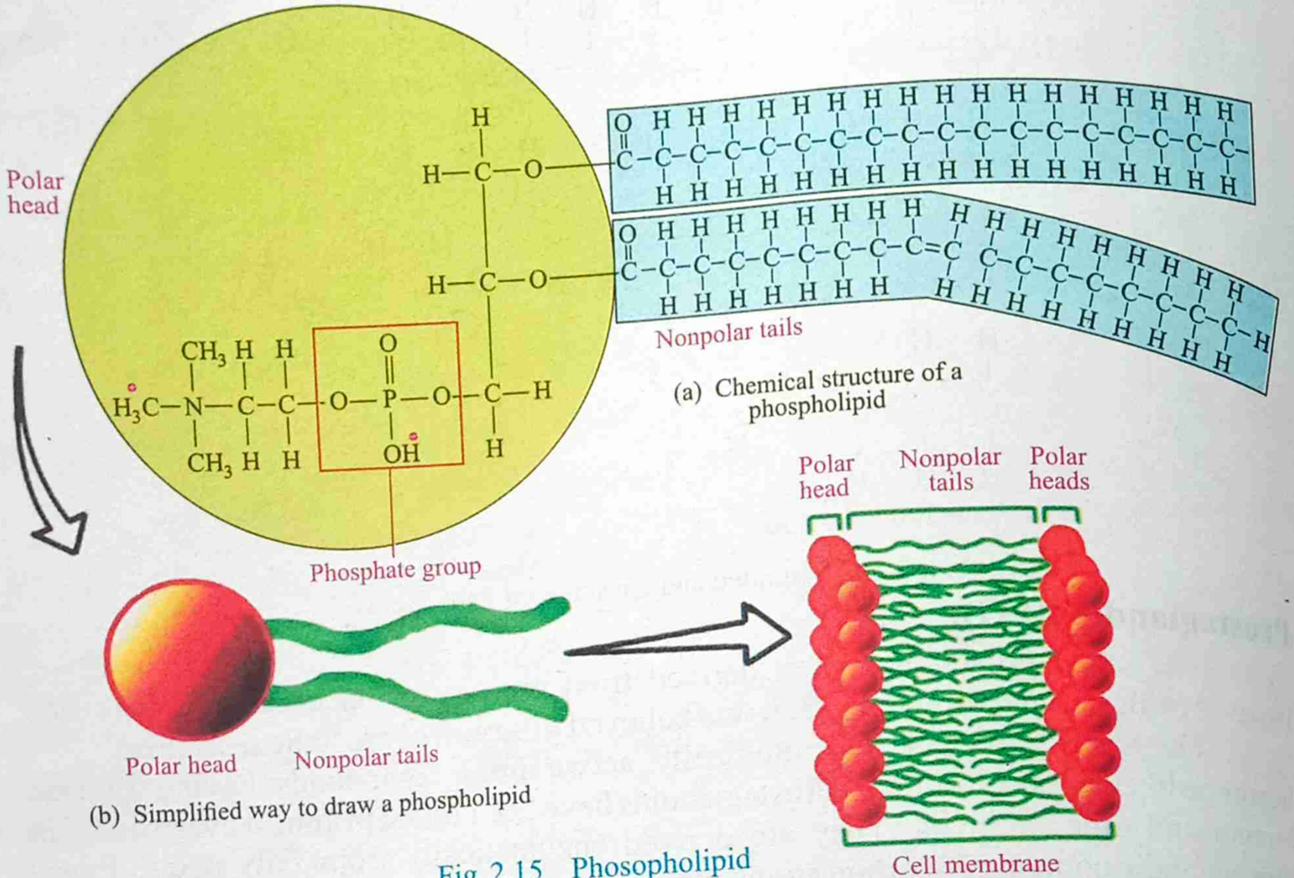


Fig. 2.15 Phosopholipid

Terpenes:

Terpenes are a large and diverse class of organic compounds, produced by a variety of plants and some insects. The building block of terpene is isoprene unit. This

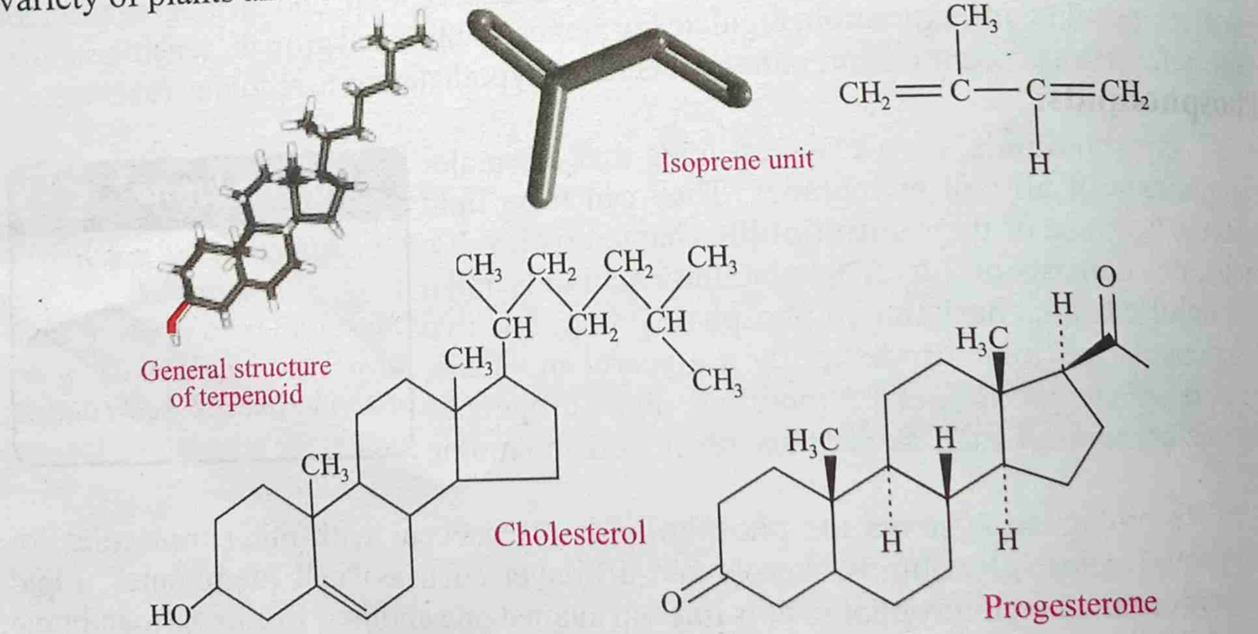


Fig. 2.16 Structure of Isoprene unit, Cholesterol and Progesterone

unit is condensed in different way to form many compounds. Two isoprene units join together to form a monoterpene $C_{10}H_{16}$ e.g., menthol and four isoprene units form a diterpene $C_{20}H_{32}$ e.g. vitamin A. Six isoprene units form triterpene $C_{30}H_{48}$ e.g., Ambrein, while rubber is a polyterpene.

Steroids:

Steroids are organic molecules and are included in lipids due to their similarities with other lipids. They are non fatty acid lipids. Their core structure is composed of 17 carbon atoms bounded in 4 interlocked rings. The first three rings are six sided while the fourth one is five sided. There are different types of steroids which vary by their functional groups attached to their four ring core.

Hundreds of steroids are found in plants, animals and fungi. All steroids are manufactured in cell.

Steroids play very important functions in the body. For example cholesterol is the structural component of cell membrane and brain tissue. Sex hormones like estrogen, progesterone in female and testosterone in male are steroids in nature. Vitamin D which regulates calcium metabolism and bile salts which emulsify fats are steroids.

Test your knowledge?

Why the use of artificial steroids are banned in sports?

Do you know?

Synthetic prostaglandins are used to induce parturition, to prevent and treat peptic ulcer, to prevent egg binding, treatment of pulmonary hypertension etc.

Do you know?

Most common type of phospholipid is phosphatidylcholine also known as lecithin.

Waxes:

They are organic compounds consist of long alkyl chain. They may also include various functional groups, fatty acids, alcohol, ketones and aldehydes.

Waxes are synthesized by many plants and animals. The most common animal wax is bee`s wax while in plants epicuticular waxes. They provide protection, act as water barrier, prevent abrassive damage etc. Cutin on leaves and fruits, suberin in plant roots are also examples of waxes.

Synthetic waxes

Waxes are used in making:

- *Plastics*
- *Candles*
- *Coatings*

2.6 Nucleic Acids

Nucleic acids are the most important and essential group of complex organic substances in living things. They are polymers of nucleotides. The principal nucleic acids, DNA and RNA are the carrier of hereditary information and control synthesis of proteins.

Nucleic acid was first isolated in 1869 by a Swiss physician, Fredrick Miescher from the nucleus of pus cells and sperms of salmon fish. He named it as nuclein (because first recorded in nucleus), later their acidic nature was observed (due to the presence of phosphoric acid) and were named nucleic acids.

Jones in 1920 proved the fact that there are two types of nucleic acids, i.e. deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).

2.6.1 Chemical constituents of nucleic acid

As already described that nucleic acids are the polymeric organic molecules which are polymerized by the condensation of monomeric units called nucleotides. Nucleic acids despite their structural and functional diversity exhibit a constant chemical composition.

Structure of nucleotides:

The partial hydrolysis of nucleic acids yield compounds known as nucleotides or nucleosides while complete hydrolysis yields a mixture of bases, pentose sugars and phosphate ions.

DNA is made up of deoxyribonucloetides while RNA is composed of ribonucleotides.

Bases:

Base is a nitrogen containing heterocyclic organic molecule. There are two main types of bases in nucleic acids. i.e. pyrimidine and purine.

Pyrimidine Bases:

These consist of nitrogen containing six corner benzene ring like structure, monocyclic. (molecular formula is **(N_2C_4)**. Three major types of bases are derived from the parent pyrimidine bases i.e. thymine, cytosine and uracil.

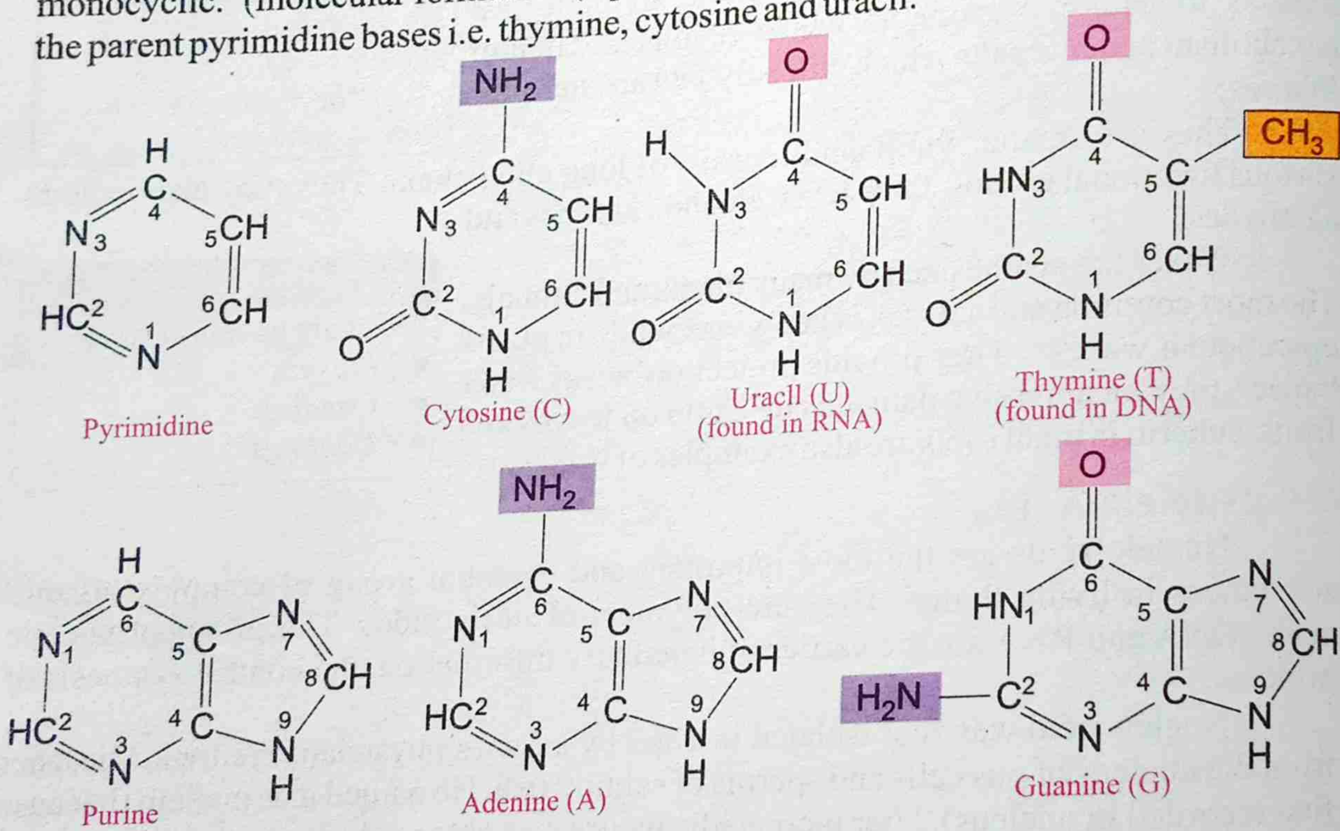


Fig. 2.17 Types of Nitrogenous Bases

Purine bases: These are second type of nitrogen containing heterocyclic organic molecules consist of two cycles. It is nine member bicyclic molecule **(N_4C_5)**. They are of

two types, i.e., adenine and guanine.

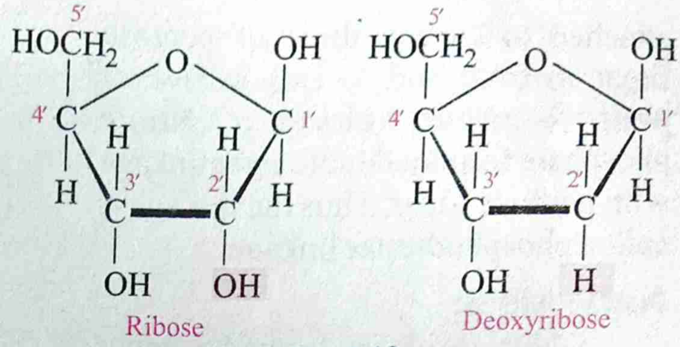


Fig. 2.18

Pentose sugars:

There are two types of 5 carbon containing pentose sugars which are yielded during complete hydrolysis of nucleic acids i.e. deoxyribose **($C_5H_{10}O_4$)** from DNA and ribose **($C_5H_{10}O_5$)** from RNA.

Deoxyribose has almost the same structure like ribose, the only difference is having one atom of oxygen less at carbon no. 2.

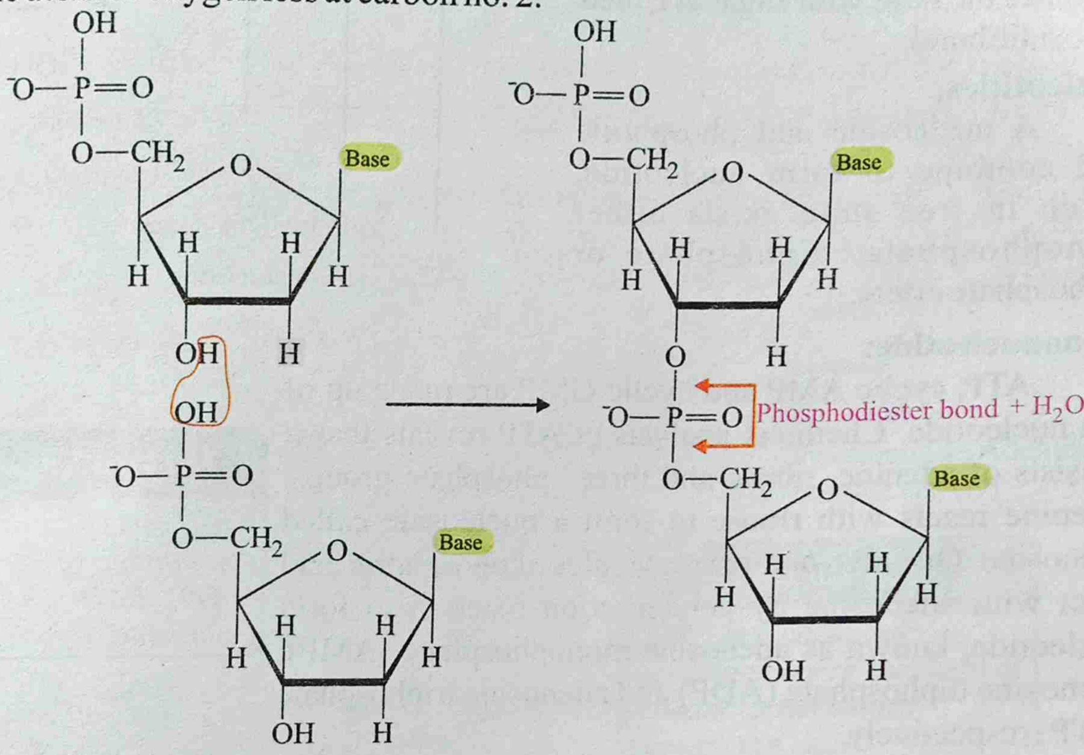


Fig. 2.19 Phosphodiester Bond

Phosphoric Acid:

Phosphoric Acid **(H_3PO_4)** has the ability to develop ester linkage with hydroxyl group (OH) of pentose sugar.

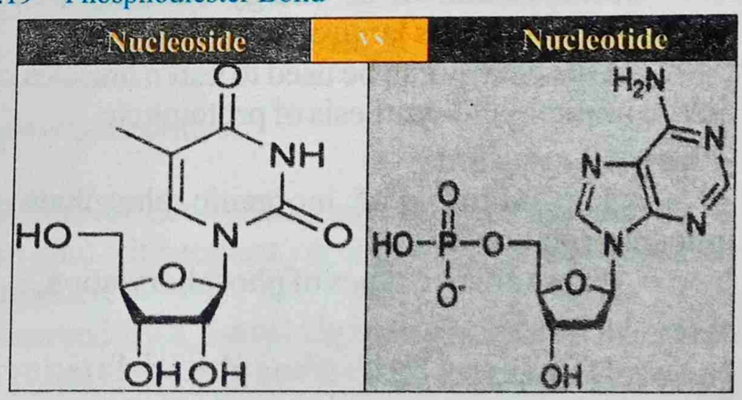


Fig. 2.20 Nucleoside and Nucleotide

Phosphodiester linkage:

In a typical nucleotide the nitrogenous base is always attached to carbon one of pentose sugar while phosphoric acid (in a chain) is

attached to carbon three of pentose sugar in front and to carbon five of pentose sugar behind it. Since phosphate forms a double ester linkage with pentose sugar. Thus the linkage is called phosphodiester linkage.

Nucleosides:

Nucleoside is formed when a nitrogen containing base is linked with a pentose sugar. The bond that combines the base with sugar is called glucosidic bond.

Nucleotides:

A nucleoside and phosphoric acid combine to form nucleotide, which in free state exists either monophosphate, diphosphate or triphosphate esters.

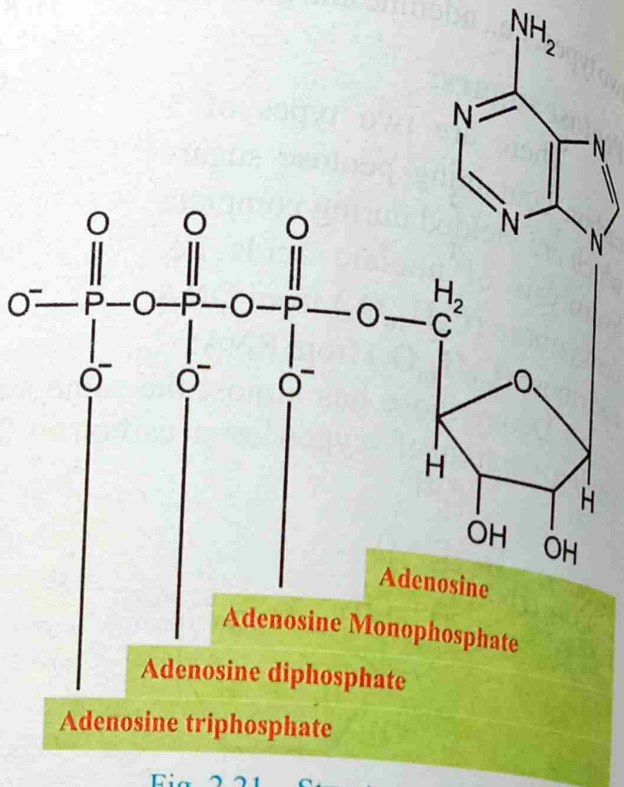


Fig. 2.21 Structure of ATP

Mononucleotide:

ATP, cyclic AMP and cyclic GMP are made up of one nucleotide. Chemical analysis of ATP reveals that it consists of adenine, ribose and three phosphate groups. Adenine reacts with ribose to form a nucleoside called adenosine. One, two or three molecules of phosphoric acid react with adenosine by condensation reaction to form nucleotide, known as adenosine monophosphate (AMP), adenosine diphosphate (ADP) and adenosine triphosphate (ATP) respectively.

Do you know?

Nucleotides are also component of ATP, cAMP, NAD, FAD and certain coenzymes.

ATP is known as energy currency of the cell, being organic phosphates on hydrolysis it releases large quantity of energy.

This energy can be used to make muscles contract, drive active transport, transmit nerve impulse and synthesis of proteins etc.

Phosphorylation:

The addition of inorganic phosphate with an organic molecule is called phosphorylation.

There are two types of phosphorylation.

1. **Photophosphorylation**

If energy for phosphosrylation comes from sunlight is called photophosphorylation e.g., formation of ATP during photosynthesis.

2. Oxidative phosphorylation

If energy for phosphorylation comes from breakdown of organic molecule in cell is called as oxidative phosphorylation. e.g., formation of ATP during cellular respiration.

Dinucleotide (Nicotinamide adenine dinucleotide NAD)

Most enzymes need additional chemical components to become functional called cofactors. Cofactors may be inorganic or organic but other than proteins are known as coenzymes e.g., nicotinamide adenine dinucleotide (NAD) and many vitamins.

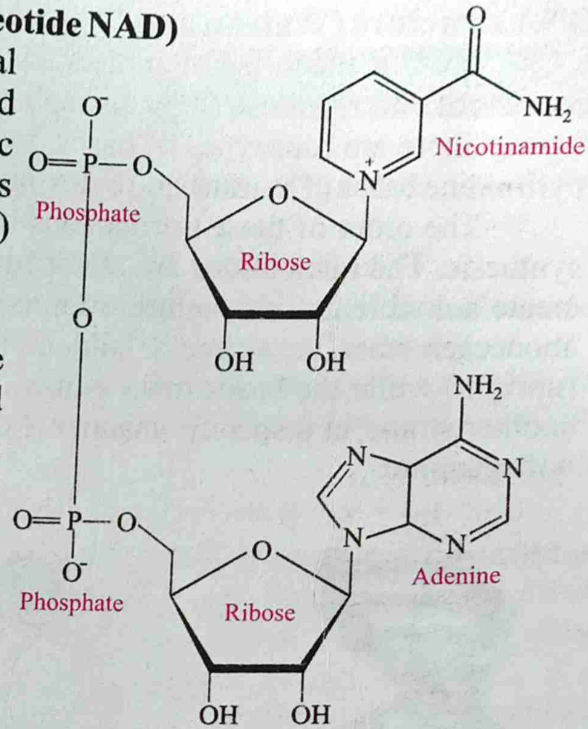


Fig. 2.22 Nicotinamide Adenine Dinucleotide (NAD)

Structure of NAD:

NAD consists of two nucleotides, one consists of nicotinamide base, sugar and phosphate group, Other consists of adenine base, sugar and phosphate group. Both nucleotides are linked by their phosphate group forming a dinucleotide. NAD is derived from nicotinic acid or niacin (vitamin B). In metabolism, NAD is involved in redox reactions, carrying electron from one reaction to other. This co-enzyme is, therefore, found in two forms in cells. NAD^+ is an oxidizing agent. It accepts two energetic electrons and a proton from other molecules and become reduced (NADH), which can be used as reducing agent to donate electorns. These electron transfer reactions are the main function of NAD.

> **Do you know?**
>
> *cAMP, is a chemical messenger, carry message of proteinous hormones through the cell.*

Another example of dinucleotide is flavin adenine dinucleotide (FAD) which is also a co-enzyme sometime used instead of NAD. It accepts two electrons (reduced) and two protons to become $FADH_2$.

Polynucleotides:

DNA and RNA are examples of polynucleotides.

Deoxyribonucleic acid (DNA):

Deoxyribonucleic acid is a polymer of deoxyribonucleotides found mostly in nucleus, few traces in mitochondrion and chloroplast. It contains instructions, an organism needs to develop, live and reproduce.

Discovery: Nucleic acid was first observed by a Swiss biochemist named Friedrich Meischer in 1869. But for long time researchers did not find its exact structure and function. It was until 1953 that James Watson, Francis Crick, Maurice Wilkins and

Rosalind Franklin figured out the structure of DNA (double helix).

Watson, Crick and Wilkins were awarded nobel prize of medicine in 1962 for giving comprehensive information for the structure and importance of DNA.

DNA structure (Watson and Crick Model of DNA):

DNA is made up of molecules called deoxyribonucleotides. Each nucleotide consists of a deoxyribose sugar, phosphate group and a nitrogen containing base.

There are four types of bases, two purine bases (Adenine and guanine) and two pyrimidine bases (Thymine and cytosine).

The order of these nitrogenous bases determines DNA's instructions for protein synthesis. The nucleotides are attached together to form two long strands that twist to create a double helix structure, running in opposite direction antiparallel and winding about each other like a circular ladder. The phosphate and sugar molecules make the sides (upright) while the bases make rungs. The bases on one strand pair with the bases on another strand in a specific manner. Adenine always pairs with thymine and cytosine with guanine.

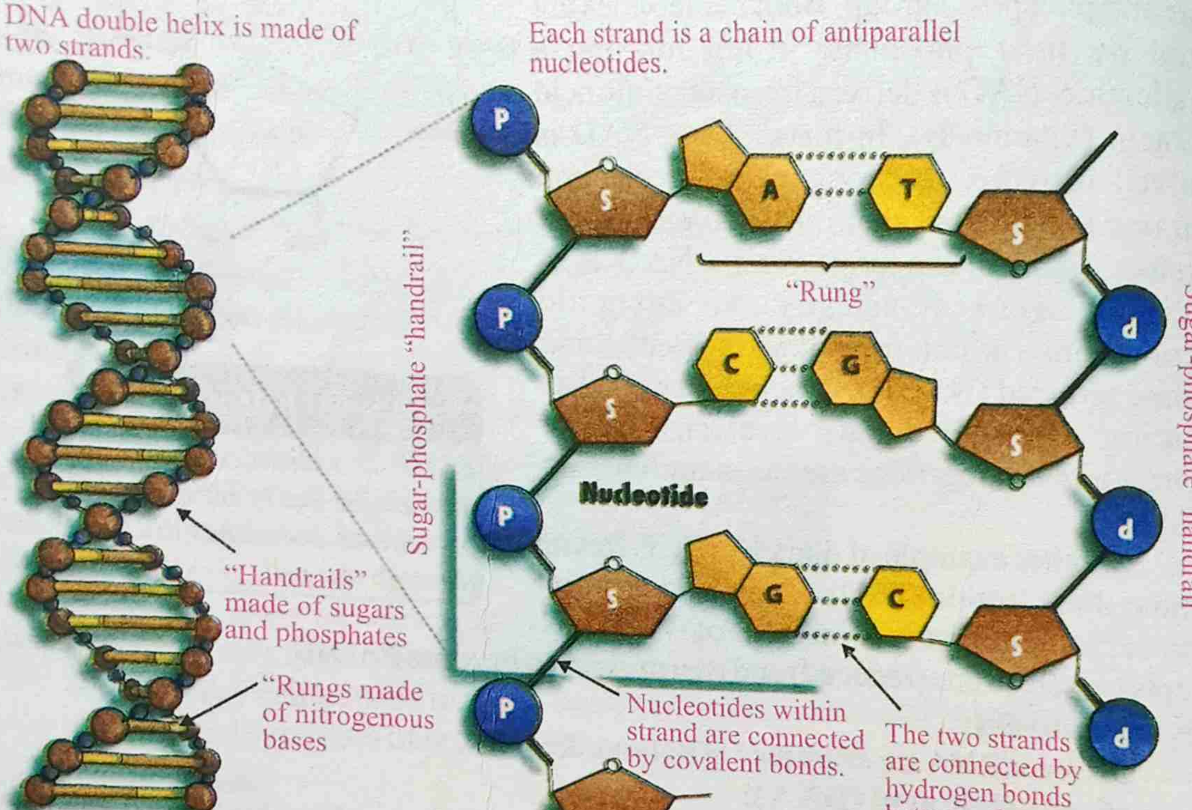


Fig. 2.23 Structure of DNA

The diameter of the two helix is 2nm and makes a full spiral turn at every 3.4nm.

The amount of DNA is fixed for a particular species as it depends upon the number of chromosomes. The amount of DNA in germ cells (sperm and egg) is half to that of somatic cells.

Structure of Ribonucleic Acid (RNA):

RNA is a long unbranched polymeric molecule formed by interlinkage of four monomeric units known as ribonucleotides of adenine, guanine, cytosine and uracil bases.

RNA molecules are single stranded, except Reo virus. However, some RNA molecules have regions in which hydrogen bonds between A = U and G ≡ C bases are formed between different regions of the same molecule thus coiled itself look like double stranded hair-pin loops. RNA is mostly present in cytoplasm but synthesized within the nucleus by using only one strand of DNA as template (3'—5') direction. Thus it is true copy of the genetic information contained in DNA. RNA helps DNA in protein synthesis. In some animal and all plant viruses, RNA functions as hereditary material. The amount of RNA varies from cell to cell.

> **Do you know?**
>
> *About 97% of transcriptional output is non protein coding in eukaryotes. So they are called non coding RNA (ncRNA).*

What is a Gene?

A gene is a region of DNA which is made up of specific sequence of nucleotides, which codes a specific polypeptide chain. A nucleotide sequence of gene in DNA specifies, the amino acid sequence of proteins through the genetic code. A set of three nucleotides known as codon each correspond to a specific amino acid e.g., if a polypeptide chain has 100 amino acids then the number of nucleotide in a gene will be 300.

Types of RNA:

There are three main types of RNA which are synthesized from different parts of DNA in a process called transcription and then are moved out in the cytoplasm to perform specific functions.

Main three types are mRNA, tRNA and rRNA.

Messenger RNA:

The mRNA is a type of RNA that carries information from DNA to the ribosomes, the site of protein synthesis in a cell. The coding sequence of mRNA determines the amino acid sequence in protein that is to be produced. There are many types of mRNA because for the translation of every polypeptide chain a specific mRNA is required. (mRNA is about 3—5% of total RNA of cell).

Transfer RNA:

The tRNA is a small RNA chain of about 80 nucleotides that transfers a specific amino acid to the growing polypeptide chain at ribosomal site of protein synthesis. There are at least 20 types of tRNA in each cell because for each amino acid a separate transfer RNA is required. About 60 types of tRNA have been identified so far. Transfer RNA are about 15% of total RNA of cell.

Ribosomal RNA:

The rRNA is the catalytic component of ribosome. It is synthesized by the genes present on DNA of several chromosomes found within the region of nucleus called nuclear organizer. The base sequence of rRNA of all organisms is similar thus there is only one type of rRNA. It is most abundant about 80% of total RNAs of the cell.

2.7 Conjugated Molecules

Conjugated molecules are types of molecules that are formed by the combination of two different classes of molecules e.g., when carbohydrate molecule combines covalently with protein, a more complex molecule is formed called glycoprotein. Some other examples of conjugated molecules are as under.

Lipoproteins: The lipoprotein forms when lipid combines with protein. These types of molecules are frequently found in cell membranes and other types of membranes in the cell like mitochondria, endoplasmic reticulum, nuclear membrane etc.

Nucleoproteins: It is formed by the combination of nucleic acid with protein e.g., Ribosome and chromosomes of eukaryotes are basically nucleoproteins in composition.

Glycolipids: These are lipids with a carbohydrate attached with glucosidic bond. Such molecules are part of cell membrane .

Table 2.3 Differences between DNA and RNA.

DNA	RNA
1. It is mainly located in the nucleus. A small quantity occurs in mitochondria and chloroplast.	1. It is mainly located in the cytoplasm. A small quantity is found in the nucleus.
2. Its quantity is constant in each cell of a species.	2. Its quantity varies in different cells.
3. It contains deoxyribose sugar. Bases are A, G, C and T.	3. It contains ribose sugar. Bases are A, G, C and U.
4. It consists of 2 polynucleotide chains held together by hydrogen bonds, and coiled into a double helix.	4. It consists of a single polynucleotide chain. It may fold on itself due to hydrogen bonds and coiled into a pseudohelix.
5. It is of 2 types: linear intranuclear and circular extranuclear.(such as in bacteria).	5. It is of 3 types: mRNA, tRNA, rRNA. Each type has many subtypes.
6. It is the genetic material in all organisms.	6. It is the genetic material only in certain viruses.
7. It transfers its information to mRNA (Transcription).	7. mRNA transfers its information to polypeptide (Translation).

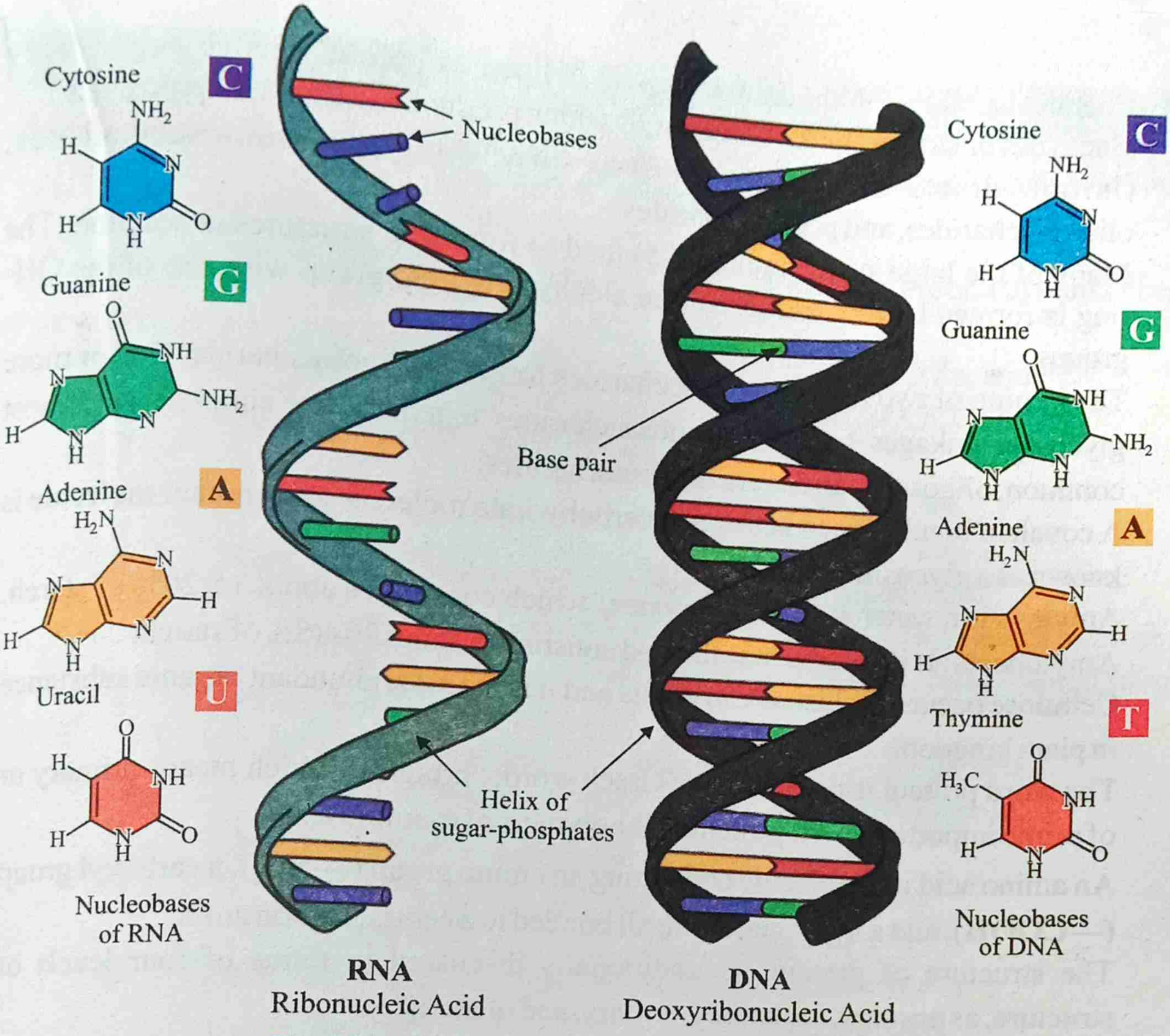


Fig. 2.24 Difference between DNA and RNA

Critical Thinking

Why reducing sugar gets red when tested with Benedict`s solution? The Benedict`s solution contains copper II salt (blue) that can be converted to copper I oxide (red). We say it has been reduced. Some sugars are able to cause this change, and thus called reducing sugars. Benedict`s test can, therefore, be used to test for the presence of reducing sugars such as glucose, fructose and maltose.

SUMMARY

- Hydrogen, oxygen, carbon, and nitrogen constitute more than 97% of the atoms in the human body.
- Water is an important compound for the life and its proper functioning is due to its polarity, low density in ice form, high heat of vaporization, high heat capacity, cohesive and adhesive properties.

EXERCISE

Section I: Objective Questions

Multiple Choice Questions

Choose the best correct answer.

A.

1. The six elements that make up 99% of all elements found in human beings are
   (a) C, H, O Na, Mg and P (b) C, N, O, S Zn, and P
   (c) H, O, C, Ca, P and N (d) C, H, O,Ca, Cu and S.
2. What are the most diverse molecules in the cell?
   (a) Lipids (b) Mineral salts
   (c) Proteins (d) Carbohydrates.
3. One of the following groups contains all polysaccharides?
   (a) Sucrose, glucose and fructose (b) Maltose, lactose and fructose
   (c) Glycogen, sucrose and maltose (d) Glycogen, cellulose and starch
4. Lactose is composed of
   (a) Glucose + galactose (b) Fructose + galactose
   (c) Glucose + fructose (d) Glucose + glucose.
5. An ATP molecule is consisting of
   (a) Mono nucleotide (b) Nucleoside
   (c) Polynucleotide (d) Vitamin
6. Lipids are insoluble in water because lipid molecules are
   (a) Hydrophilic (b) Hydrophobic
   (c) Neutral (d) Polar
7. In double helix of DNA, the two DNA strands are
   (a) Coiled around a common axis (b) Coiled around each other
   (c) Coiled differently (d) coiled over protein sheath.
8. In DNA the nitrogenous base that takes place of uracil is:
   (a) Thymine (b) Adenine
   (c) Guanine (d) Cytosine
9. Proteins are synthesized from
   (a) Glucose (b) Fatty acids
   (c) Amino acids (d) A-ketoglutaric acid.

B. **Fill in the Blanks.**

1. The branch of biology which deals with the chemical compounds and chemical processes is called ______.